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ZAKONOMERNOSTI DINAMIKI CHISLENNOSTI KETY BASSAEINA REKI KAMCHATKI

LAWS GOVERNING THE DYNAMICS OF THE POPULATION SIZE OF CHUM IN THE BASIN OF THE KAMCHATKA RIVER

By E.T. Nikolaeva (Kamchatka Division of the Pacific Scientific Research Institute of Fisheries and Oceanography)

Long-term forecasts concerning the numbers of Pacific salmon often do not prove their value. The present study was undertaken to improve the estimates of the chum stock, a species of salmon which after pink salmon is next in commercial and economic importance in the Far East, including Kamchatka. Taking as an example the large commercial population of chum in the basin of the Kamchatka River, the study aimed at establishing the basic laws that govern the dynamics of the stock and, using this information, at developing a methodology of long-term forecasting and a set of recommendations for a rational exploitation of the stock. This goal required a solution to a number of interconnected problems, such as evaluating the stock over a number of years and the number of chum generations from the age of sexually mature fishes, establishing the ratio of parental and filial generations and determining the optimal number of spawners, determining the main abiotic and biotic factors that regulate the reproduction levels, and establishing the effect of the size of our own generations of chum and the generations of pink salmon of the north-eastern coast of Kamchatka on the population's reproduction rates. Moreover, in order to estimate the spawning stock of chum in the Kamchatka River, it was necessary for our marine operation to be able to identify this salmon species from the structure of the scales.

The study uses Soviet and Japanese statistics on the Kamchatka

River chum caught in the sea (1952-1976), at the coast (1937-1986), as well as data on the numbers of spawners at the spawning grounds (1945-1986). Biosamples in the amount of 300-600 specimens were taken according to standard methodology during the fishing season every year, starting in 1945, at the Ust'-Kamchatskii fish-processing plant. The age composition of the catch taken from the sea and from the spawning grounds /2 was compared with that of the fishes caught in the coastal zone. In developing the methodology for identifying the origin of chum caught at sea, we studied scale samples from 21 runs (Fig. 1) within the limits of the entire spawning area of the species. The established ratio of chum of various origins caught at sea in 1975-1976 was extrapolated to all the previous years. The monthly hydrometeorological reports, starting with 1945, were provided by the Hydrometeorological Service "Klyuchi" located at the center of the river system. The data were treated according to the generally accepted methodology. The correlation coefficients, the systems of linear discriminant functions, Ricker's reproduction curves, the equations of simple and multiple linear regression were calculated with the "Nairi-K" computer.

RESULTS OF THE STUDY

The chum salmon are more numerous on Kamchatka than in any other large region of the Far East. In the prewar years, twenty-five million fishes were caught at the coasts of Kamchatka, eleven million at the northern coast of the Sea of Okhotsk, and a total of ten and a half million in other regions, including Japan.

The chum stock of the Kamchatka River is the largest in the river system of the eastern coast of the peninsula (Fig. 2). Its commercial significancewas particularly high during the twenty-year period (1957-1977) of depressed chum stocks in the north-east of Kamchatka. The maximum catches amounted to 5000 tons, dropping to a minimum of to 300 tons. Starting with 1939, the year marked by high catches, the following peaks return unmistakably every forth year and correspond to ood years (1943, 1947, 1951, 1955, 1959, 1963). In 1967 the catches dropped off abruptly and the cycle was disrupted. They became higher in this cycle only in

1979 and the cyclicity subsequently became based on two-year periods.

The chum of the Kamchatka River, like in other large populations, mature at the age of 2 to 6. Among mature fishes four-year old specimens prevail in most cases (Fig. 3). The cyclicity of high catches corresponds to this age group and has been maintained at the expense of one generation /3
of the dominant line. This is undoubtedly so, since five-year old specimens prevailed in the run only in those even years (1952, 1956, 1960, 1980, 1984) which follow the odd ones with increased levels of catch.

An exception is the year 1967, when not only the numbers changed, but also the age structure of the population was disrupted. Instead of the traditional four-year olds (3+), five-year olds (4+) prevailed in numbers like in the above-mentioned even years, so that the generation of 1963 lost its commercial importance. Thus, four-year and two-year cyclicity is typical of the numbers of chum generations in the Kamchatka River. Such a cyclicity of year-class strength is characteristic of other chum populations and of other salmon species.

Judging from the dynamics of daily catches, which are shown in five-day periods on Fig. 4, the spawning run of the Kamchatka River chum is lengthy, which is proof of the complex structure of the species in this area. According to some reports, three forms of of chum salmon - spring, summer, and fall - are being reproduced in the Kamchatka River. The curve reflecting the heaviest run of chum (1963) permits one to conclude that the summer chum are the most numerous and form the basis of the industry. Parting from the dates at which the run begins, it is difficult to estimate its overall strength, although a concerted uninterrupted start of the run witha high number of five-year olds participating may be an indication of the low number of chum (1967, 1971, 1980).

The discriminant analysis of five established differentiating criteria in reference to the scales of the first year of growth (Fig. 5) affords a quick method for reliably identifying the Kamchatka River chum in the overall marine catches of chum salmon. The error with regard to other populations fluctuates between 0.0003 to 31%. The year and age-related changes in the structure of the scales require that samples be taken an-

nually to establish the standard criteria and compute the systems of linear discriminant functions with regard to the main age groups of fishes of the populations that are being differentiated.

The materials quoted on the ratio of filial and paternal generations /4
(Fig. 6) characterize the ascending branch of the curve of reproduction. No cases of crowding the spawning grounds by spawners were observed, their evident deficiency was frequent. The correlation coefficient between these magnitudes was positive reliable but not high ($r=+0.38$; $P=0.05$). It is interesting that for the generations of odd years, of high yield for the most part, it corresponds to the average level ($r = + 0.48$), while in generations of even years, low in yield, there is no correlation ($r = + 0.05$). The optimal number of spawners according to the given curve is 0.4 million fishes. But in highly productive generations the number of spawners was 0.6 million. Beginning with 1982, the escapement has been catastrophically low, amounting to 25-30% of the optimal figure, and overfishing is to blame for it. This population is characterized by expanded reproduction, extreme conditions being rare - in 3 out of 27 generations (1945, 1948, 1963). The straggling of points is considerable and it is impossible to predict the productivity of a generation on the basis of the number of spawners.

Reflecting the correlation "parents-offspring", the multiplicity index of reproduction is extremely variable (Fig. 7), the minimal (0.17) value being 111 times smaller than the maximum value (18.94). The relation to the number of spawners is negative highly reliable ($r = - 0.47$; $P < 0.01$). Its variability is characterized by 22-year sun-determined cyclicity. In odd-year generations a cyclicity close to 22 years has been observed (maximum values correspond to the generations of 1953 and 197- last digit missing, Tr.), in even-year generations there is a clear 8-year cyclicity (peaks corresponding to the generations of 1950, 1958, 1966, 1974), Fig. 8.

As a result of an extensive correlative-regressive analysis, it was established that 92.2% of the dispersion of the reproduction multiplicity index in odd-year generations can be explained by the variability of nine

factors. The complex includes the number of spawners, their quality (average value of age and body mass), the amount of precipitation during the month of January, the height of the snow cover in February and the water level in December, February, March and April. The most important in this complex are the amount of precipitation, the water level in December and February, as well as the age of spawners; the partial correlation coefficients are equal to: -0.85; + 0.82; - 0.72; + 0.71 /5

The high (11.0, 14.0), as well as the low (0.17) values for the reproduction multiplicity index (Fi. 8 a) coincide with the corresponding values for the level of precipitation in January (158, 111, and a total of 13.3 mm). This abiotic factor for the generation of 1963 proved to be extremely low. The low level of precipitation was during the period of development of two successive generations of the dominant line (1967; 1971) 40 and 60 mm. And only in 1976 there were 150 mm of precipitation in January, which gave the generation of 1975 - the spawning grounds being relatively unoccupied - a chance to bring the numbers of offspring to the average level. The unfavorable conditions were the main reason for a sharp drop in the numbers of chum in the Kamchatka River in the late 60's and early 70's and the disruption of the 4-year cyclicity in the size of generations. Fishing at open sea worsened the depression of the population and hindered rebuilding of the stock.

The nine-factor complex proved to be of little effect for the even-year generations: R = 0.71. The maximum dispersion of the reproduction multiplicity index in even-year generations, but only at the level of 72.2%, is explained by the variability of 7 variables. The complex includes the number and quality of spawners, the amount of precipitation in January, the average water level in December-April, the size of the following odd-year generation of the Kamchatka River chum and the size of the even-year generation of pink salmon. The main factors here proved to be the numbers of pink salmon and the average values of age and body mass of spawners (partial coefficients of correlation equal to - 0.68; + 0.56; + 0.41.)

The equations of multiple linear regression computed on the basis of the established factors reproduce satisfactorily the actual values

of the reproduction multiplicity index. The theoretical series of the index of odd-year generations includes 5.5% (Fig. 9) and of even-year generations 12.5% gross (in the 20%-limit and over) errors. /6

As far as the rate of maturation of chum is concerned, it has been established on the basis of two populations -Kamchatka and Bol'shaya Rivers - that a differentiation of fishes into two separate age groups takes place in the generations when they reach the age of two (1+) or three (2+) years. A relation was discovered between the number of foraging fishes in these critical moments and the average age of maturation of chum generations. The correlation coefficient with the number of chum generations (Fig. 10) is equal to 0.57, and with the number of even-year generations of pink salmon it is 0.70. At the same time, the correlation coefficient for even-year chum generations in the first case (Fig. 10) is equal to 0.86, in the second case (Fig. 11) to 0.90, whereas for the odd-year generations of chum it is 0.15 and 0.34 respectively. Utilizing the established relations, we computed the equations of simple linear regression, on the basis of which it is possible to forecast satisfactorily the average maturation age of the generations of Kamchatka River chum. The latter serves, also on the basis of computed equations of simple linear regression, to determine the participation of the main age groups of fishes (3+ and 4+) in the spawning runs. The established laws of the dynamics of population size of the Kamchatka River chum have increased the reliability of forecasting and have allowed us to concluded that the stocks will be at a low level for the next 10-15 years.

Captions to the figures of E.T. Nikolaeva's paper LAWS GOVERNING THE DYNAMICS OF THE POPULATION SIZE OF CHUM IN THE BASIN OF THE KAMCHATKA RIVER /7

Fig. 1. The area of chum and the populations in which scale samples have been studied.

Fig. 2. Catches at the eastern coast of Kamchatka /1/ and in the Kamchatka River basin /2/.

Fig. 3. The number of four-year olds in the chum populations of the Kamchatka and Bol'shaya Rivers during the spawning run.

Fig. 4. Catch distribution of Kamchatka River chum during the years of variable-strength spawning run.

Fig. 5. The variability of scale criteria in chum during the first year of life: a - number of sclerites; δ - width of "winter ring", mm; β - width of three sclerites, Γ - width of seven sclerites, Δ - width of five sclerites. The vertical line indicates the general variability amplitude of trait frequency, the wide black line - the interval equal to one sigma to either side of the average, the uncolored rectangular - the interval corresponding to double the standard error, the transversal line - mean value of the trait.

Fig. 6. Correlation of the size of parental and filial generations of Kamchatka River chum /1945-1971/.

Fig. 7. The number of spawners /1/, reproduction multiplicity index /2/ of generations of Kamchatka River chum for 1945-1979 and solar activity /3/.

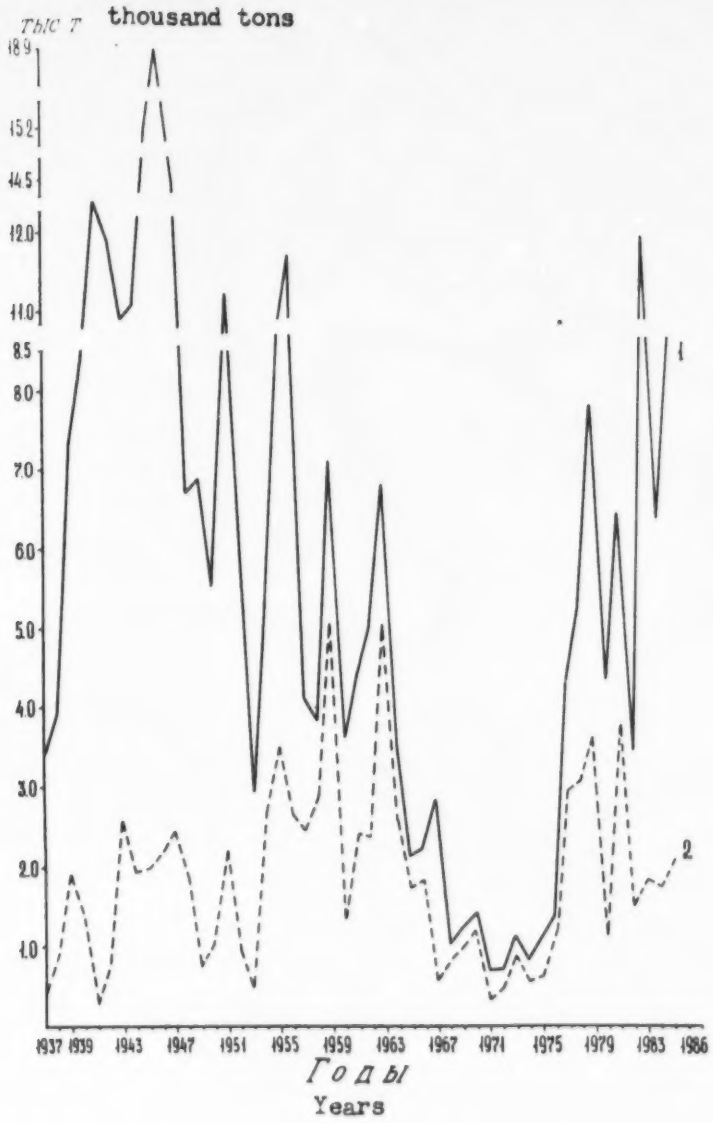
Fig. 8. Average age of spawners /1/, the amount of precipitation during January /2/ and the reproduction multiplicity index /3/ for generations of Kamchatka River chum of odd (a) and even (δ) years of reproduction.

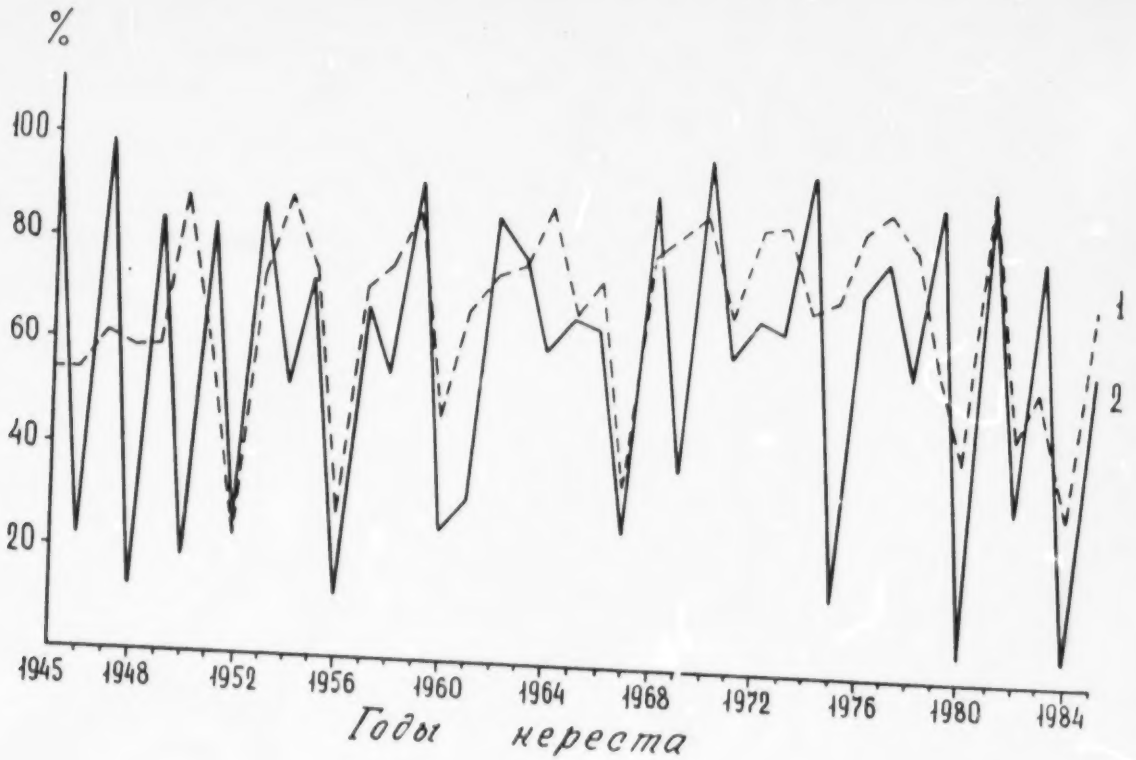
Fig. 9. Actual /1/ and theoretical /2/ values of the reproduction multiplicity index for odd-year generations of Kamchatka River chum.

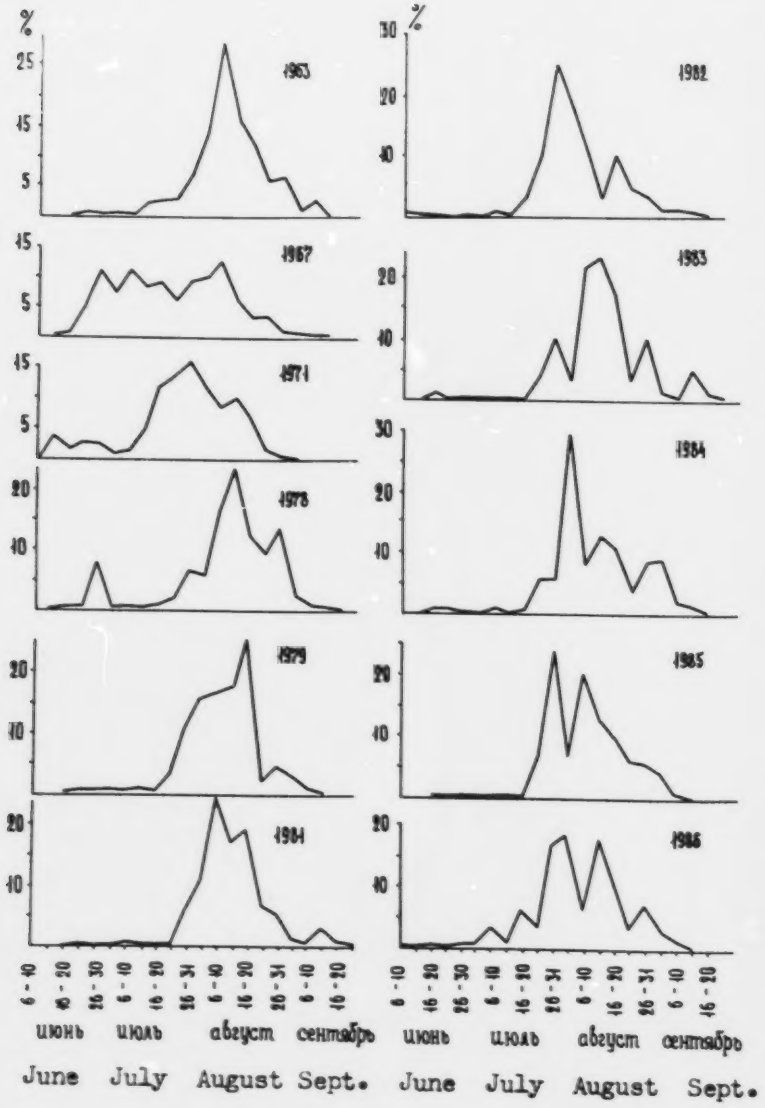
Fig. 10. Average age of sexual maturation of one generation depending on the size of four generations of Kamchatka River chum (1952-1977). The dotted line

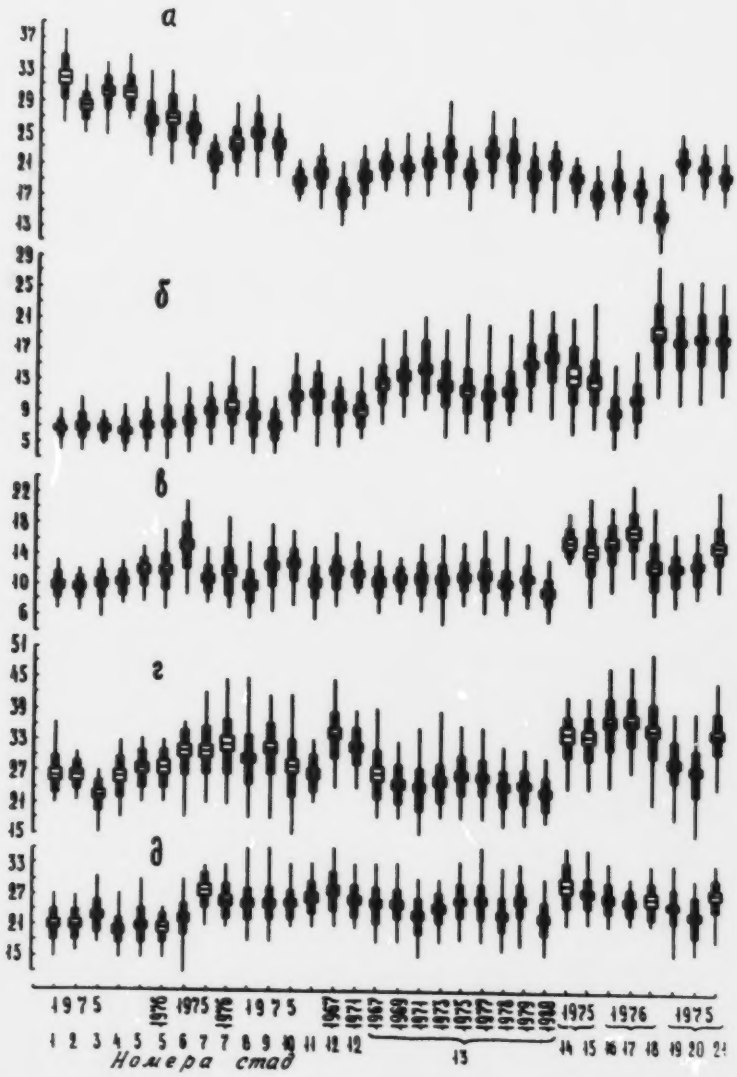
reflects the correlation of sizes of the generations of all the years, /8
the unbroken line - of the even-year generations.

Fig. 11. The average age of sexual maturation of generations of Kamchatka River chum (1955-1978) depending on the size of pink salmon generations at the north-eastern coast of Kamchatka for the odd reproduction years (symbols as in Fig. 10).

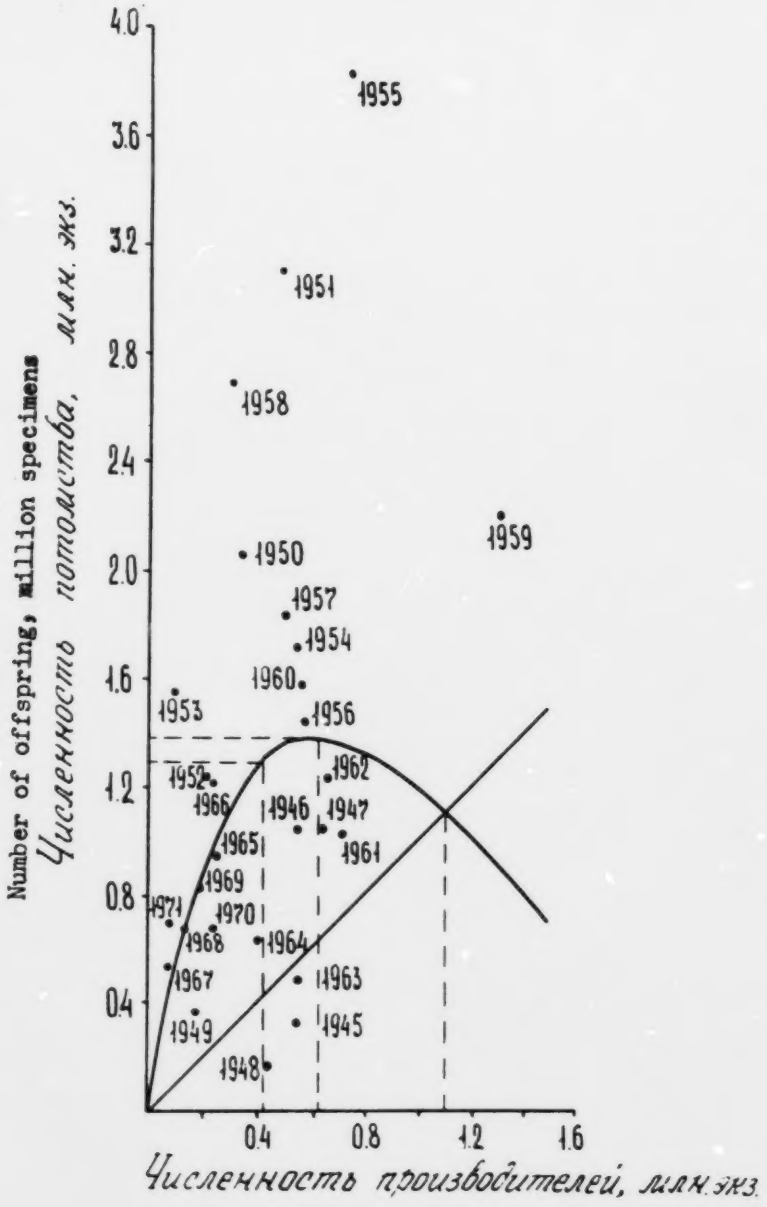

тыс т
thousand tons
18.9
15.2
14.5
12.0
11.0
8.5
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
1
2
1937 1939 1943 1947 1951 1955 1959 1963 1967 1971 1975 1979 1983 1986
Годы
Years

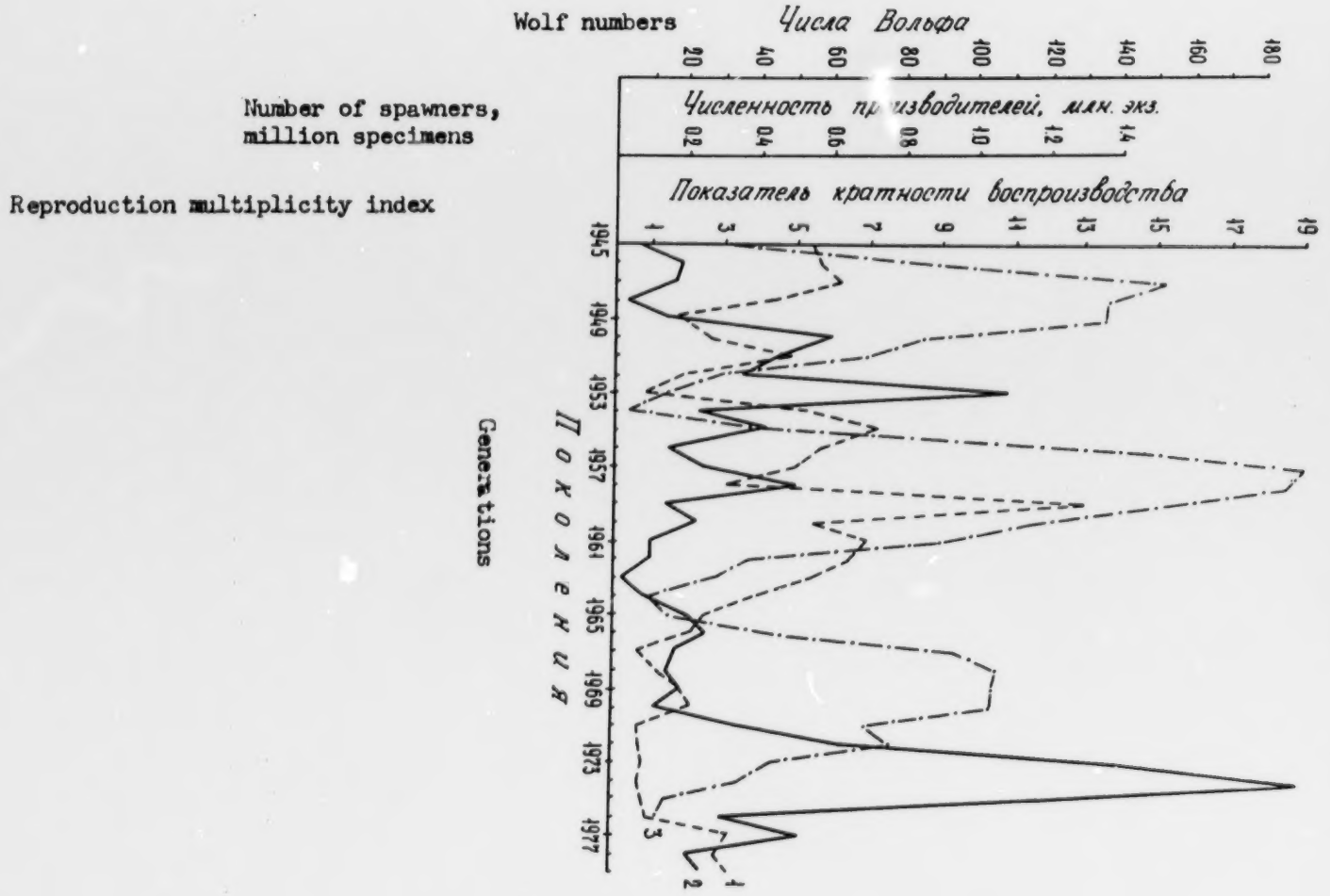

%
100
80
60
40
20
1945
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1
2
Годы нереста
Years of spawning

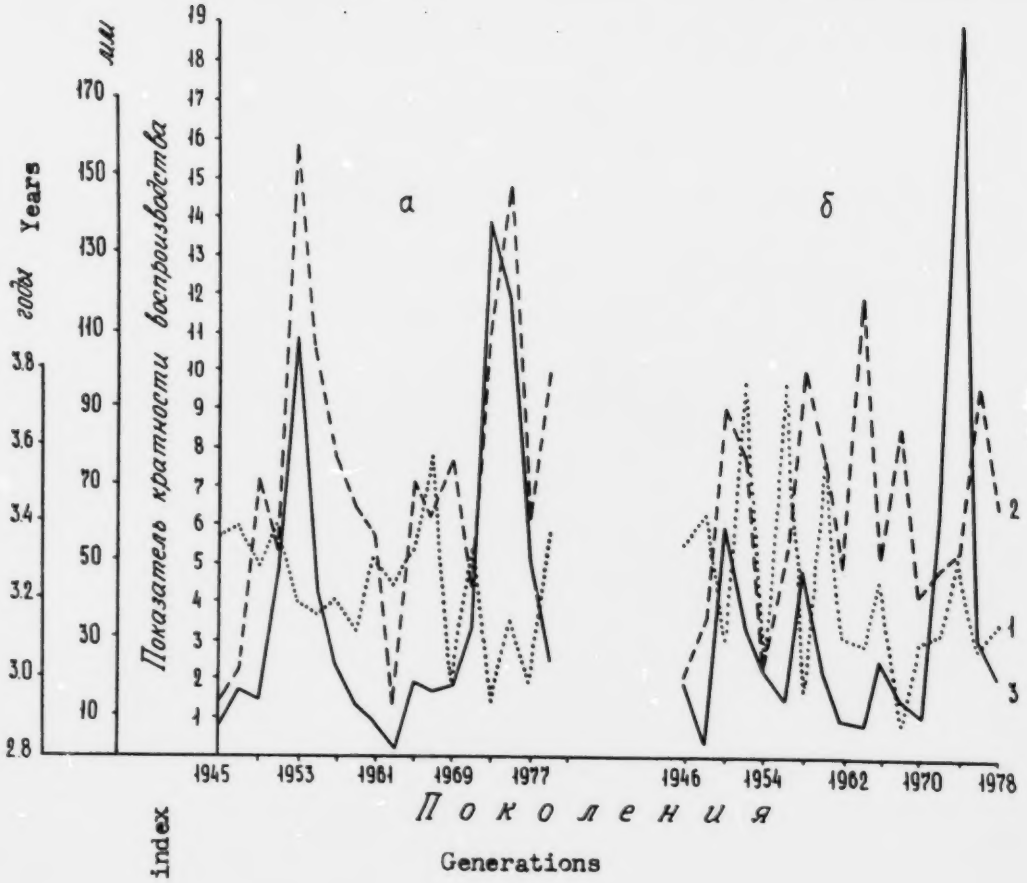

%
1963
1967
1971
1978
1979
1984
1982
1983
1984
1985
1986
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31
июнь
июль
август
сентябрь
June
July
August
Sept.

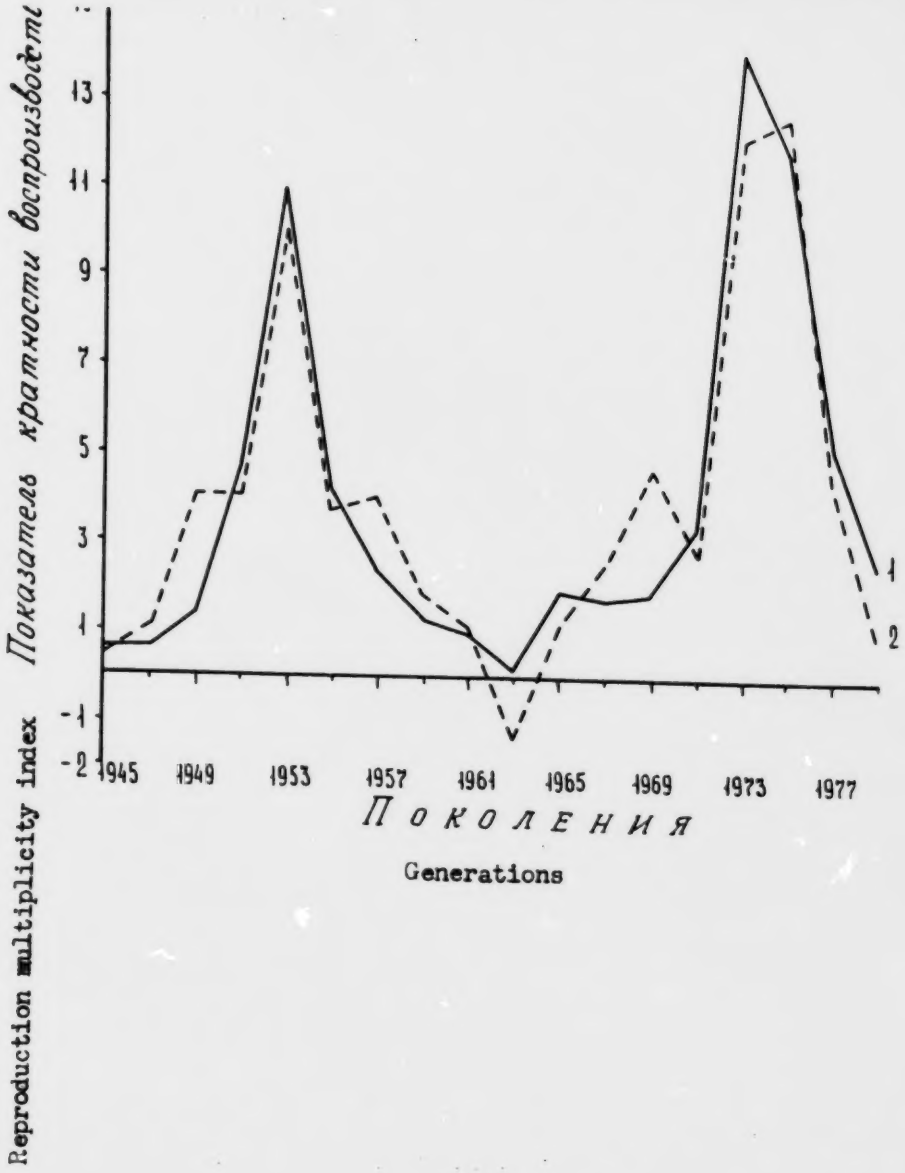


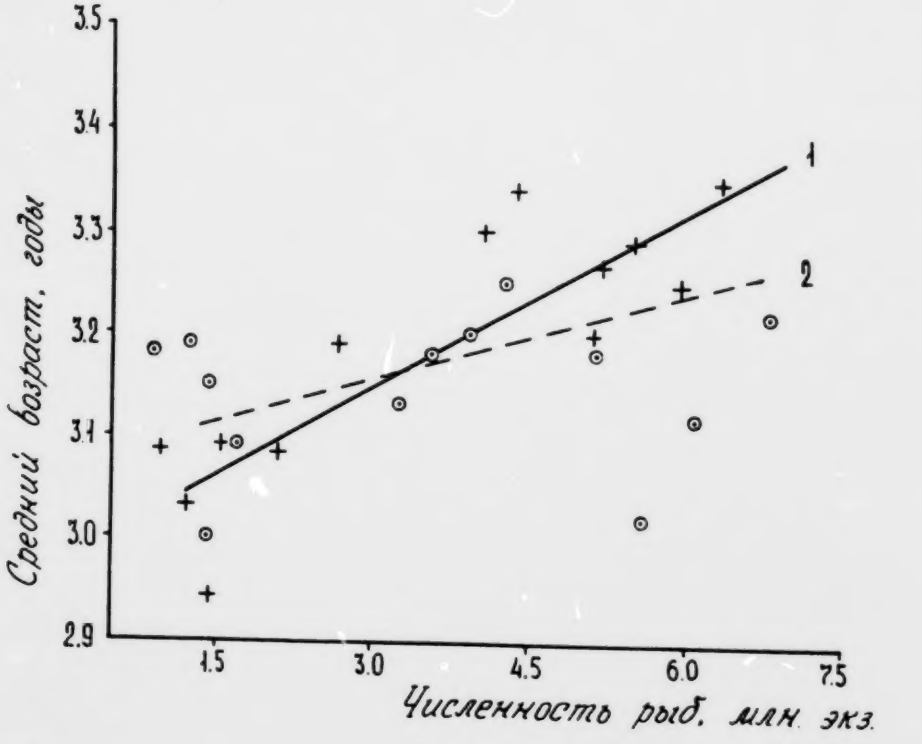
Numbers of populations

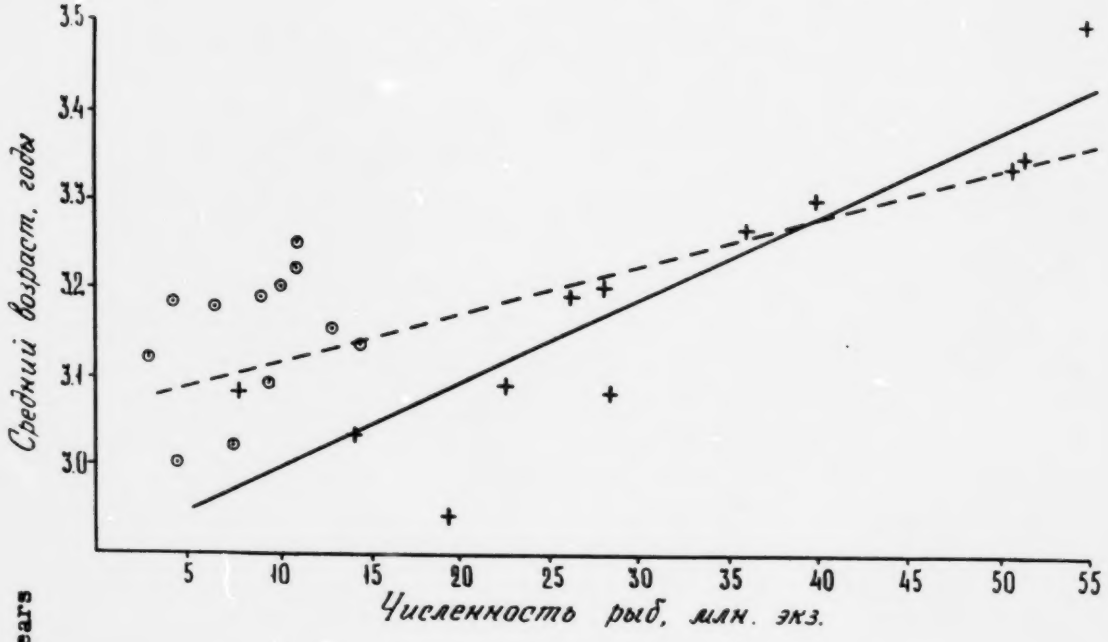

Number of offspring, million specimens
Численность потомства, млн. экз.
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.4
0.8
1.2
1.6
1955
1951
1958
1959
1950
1957
1954
1960
1953
1956
1952
1962
1966
1946
1947
1965
1961
1969
1971
1970
1968
1964
1967
1963
1949
1945
1948
Численность производителей, млн. экз.
Number of spawners, million specimens


Wolf numbers
Числа Вольфа
20 40 60 80 100 120 140 160 180
Численность производителей, млн. экз.
0.2 0.4 0.6 0.8 1.0 1.2 1.4
Показатель кратности воспроизводства
1 3 5 7 9 11 13 15 17 19
Number of spawners, million specimens
Reproduction multiplicity index
Generations
Поколения
1945
1949
1953
1957
1961
1965
1969
1973
1977
1
2
3


лет
170
150
130
110
90
70
50
30
10
годы Years
3.8
3.6
3.4
3.2
3.0
2.8
Показатель кратности воспроизводства
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
а
б
1
2
3
1945
1953
1961
1969
1977
1946
1954
1962
1970
1978
Поколения
Generations
Reproduction multiplicity index


Показатель кратности воспроизводства
Reproduction multiplicity index
13
11
9
7
5
3
1
-1
-2
1945
1949
1953
1957
1961
1965
1969
1973
1977
1
2
Поколения
Generations


3.5
3.4
3.3
3.2
3.1
3.0
2.9
1.5
3.0
4.5
6.0
7.5
1
2
Средний возраст, годы
Численность рыб. млн. экз.
Average age, years
Number of fishes, million specimens



Average age, years

Number of fishes, million specimens